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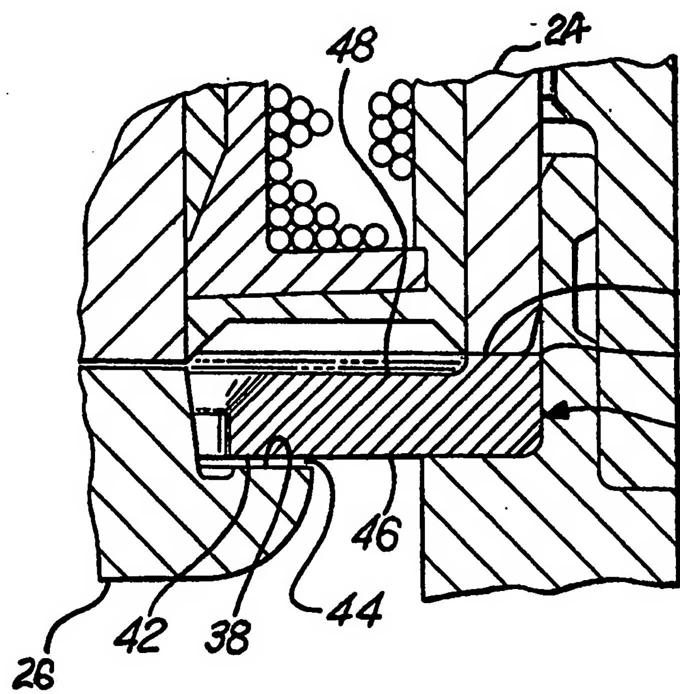
(54) Title: METHOD OF ADJUSTING A SOLENOID AIR GAP

(57) Abstract

The air gap (44) for a solenoid device, such as an engine fuel injector, is adjusted during assembly by determining the gap defining dimensions of all but one of the magnetic elements of the solenoid assembly, determining the dimensions of the one element needed to form the desired air gap upon assembly with the others and sizing the one element to the required dimensions by deformation of a preform. In a preferred embodiment, a flux washer (28) for engaging one pole of a stator (24) and to be spaced by an air gap (44) from another pole (38) of an armature (26) is crushed prior to assembly to a predetermined thickness determined to provide the desired air gap when assembled with premeasured elements into an assembly. Sizing of the flux washer, or other magnetic element, by plastic deformation, such as crushing, avoids sorting and selection of a flux washer from an inventory of various sizes of flux washers stored at the assembly site, thereby minimizing the time and cost of assembly.



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METHOD OF ADJUSTING A SOLENOID AIR GAP

Field of the Invention

This invention relates to solenoid devices including an air gap and, in a particular embodiment, to a valve actuating solenoid in an engine fuel injector.

Background of the Invention

It is known in the art to provide a solenoid actuating device, such as a valve actuator for an engine fuel injector, with a solenoid actuator having a prescribed air gap. In a particular embodiment for an engine fuel injector, the solenoid may have an actuating coil surrounded on its inner, outer, and upper sides, for example, by a stator of magnetic material and having inner and outer annular poles extending to an open end. A moveable armature is provided that is connected with an injector valve needle or other moveable element. The armature has inner and outer poles, one of which, preferably the inner one, is engageable with the inner pole of the stator when the solenoid coil is energized. The outer pole of the armature lies opposite a lower face of a flux washer which is mounted with its outer edge in engagement with the outer pole of the stator. The stator, armature and flux washer are all made from magnetic material to concentrate the magnetic field developed by the coil.

When the coil is energized, the armature is moved into engagement with the inner pole of the stator, leaving a preselected air gap between the outer pole of the armature and the opposed face of the flux washer. In assembly, the desired spacing of the air gap is obtained by selection of a washer of the proper thickness from a group of washers of various thicknesses made in advance and stored at the assembly location for use as needed. This method requires some sorting of parts at the time of assembly and the keeping of an inventory of different sized washer elements within the tolerance range, Inevitably, some of the parts will be unusable due to tolerance stack-ups in manufacture and the gap may not be controlled to the desired tolerance.

Summary of the Invention

The present invention provides a method for sizing the air gap at assembly without requiring an inventory of presized flux washers or other components and without requiring selection or sorting of these parts at the assembly station. As used in a preferred embodiment within an engine fuel injector having a stator, armature and flux washer as previously described, the method involves the steps of:

determining the gap defining dimensions of all but one of the elements;

determining the dimensions required for said one element to form the desired air gap upon assembly with the others of said elements; and

sizing said one element to the required dimensions (the latter step was previously done by selection);

characterized in that sizing of the one element to the required dimensions is carried out by deformation of a preform.

Preferably the preform which is sized is a flux washer preform which has been previously fabricated by machining, cold forming, powered metal processing, metal injection molding or any other suitable process. It may be plated with a suitable malleable coating for corrosion or magnetic reasons.

Sizing of the flux washer preform at assembly is preferably accomplished by crushing or squeezing the washer, or at least the gap forming portion thereof, to the required dimension determined for the particular solenoid assembly by the previous method steps. Such sizing by crushing is easily accomplished by a press located at the assembly site. The properly sized flux washer is then installed in the assembly to form the desired air gap in the specific injector assembly for which it has been sized. If necessary, magnetic degradation of the deformed flux washer component can be removed by induction annealing prior to assembly.

In an alternative method of assembly, the air gap may be determined by crushing one of the pole faces of either the armature or the stator. In yet another method, the air gap of the assembled unit

may be obtained by bending the web portion of the stator located between the inner and outer cylindrical poles. The web of the armature could alternatively be bent for this purpose.

These and other features and advantages of the invention will be more fully understood from the following description of certain exemplary embodiments of the invention taken together with the accompanying drawings.

Brief Description of the Drawings

In the drawings:

FIG. 1 is a cross-sectional view of an exemplary form of engine fuel injector having a valve actuating solenoid formed in accordance with the invention;

FIG. 2 is an enlarged cross-sectional view showing one form of flux washer used with the solenoid of FIG. 1;

FIG. 3 is a view similar to FIG. 2 but showing an alternative embodiment of flux washer; and

FIG. 4 is a view similar to FIGS. 2-3 but showing another embodiment of flux washer.

Detailed Description of the Invention

Referring first to FIG. 1 of the drawings in detail, numeral 10 generally indicates an engine fuel injector having a body 12 carrying an injection nozzle 14 controlled by a reciprocable valve needle 16. The valve needle is urged in a closing direction by a spring 18 and is actuated open by the force of a solenoid generally indicated by numeral 20. Solenoid 20 includes a coil 22, stator 24, armature 26 and flux washer 28. The stator, armature and flux washer are all made of magnetic material for concentrating the magnetic force generated by the coil 22.

The coil 22 is formed as a cylindrically wound electric coil enclosed in a cylindrical casing. The stator includes a web 30 extending across the upper end of the coil and connecting with a cylindrical inner pole 32 and a cylindrical outer pole 34 that extend from the web along inner and outer sides of the coil to spaced lower

ends. The armature 26 is fixed to the valve needle 16 and reciprocable therewith. The armature 26 includes an inner pole 36 having an annular face that is engageable with the lower end of the inner pole 32 of the stator. Pole 36 is connected by a short web 37 with an outer pole 38 having an annular face spaced outwardly and downwardly from that of the inner pole. The flux washer 28 is secured within the body 12 and has an upwardly facing outer surface 40 engaging the lower end of the stator outer pole 34. Washer 28 also has a downwardly facing inner face 42 which is located in opposed relation to the annular end of the outer pole 38 of the armature.

When the solenoid 20 is energized, the armature 26 is pulled upward against the force of spring 18, raising the needle 16 to open the valve for the injection of fuel. This upward motion of the armature moves the inner pole 36 into engagement with the inner pole 32 of the stator. In this position, an air gap 44 of preselected dimensional thickness exists between the inner face 42 of the flux washer, which faces downward, and the annular face of the armature outer pole 38. Precise sizing of this outer air gap 44 is desired to provide optimal and consistent performance of the various similarly assembled injectors used within an engine and/or manufactured from the same source.

FIGS. 2, 3 and 4 illustrate three differing forms of flux washers which could be used in a solenoid according to the invention. In FIG. 2, the flux washer 28 is shown as having a flat lower wall 46 and a parallel upper wall 48 with a raised outer rim 50 having an upper face 40 engageable with the annular end of outer pole 34 of the stator. The inner portion of the lower wall 46 defines the inner face 42 of the flux washer and the air gap 44 is shown between face 42 and the annular face of the armature outer pole 38.

FIG. 3 shows an alternative embodiment of flux washer 52 wherein like numerals are used for like features. Washer 52 differs in its provision of an inner rim 54 on the inner edge of the upper wall 48 for a purpose to be subsequently described.

In FIG. 4, another embodiment of flux washer 56 is illustrated in which both rims of the previous designs are omitted and the lower and

upper walls 46, 48 are both flat. In this embodiment, the outer portion of upper wall 48 defines the outer face, while the inner portion of lower wall 46 defines the inner face 42.

In order to provide a consistent dimensional thickness of the air gap 44 in all injectors of a common design, the invention provides a novel process including the following steps for use in the manufacturing process:

First, determine the gap defining dimensions of all but one of the stator, armature and flux washer elements. For example, the outer and inner elevations, or height differences, of the armature and stator inner and outer poles may be measured.

Second, determine the dimension of the one remaining element, preferably the flux washer, that are required to form the desired air gap upon assembly with the other elements. For example, the elevations of the inner poles may be summed, the elevations of the outer poles added together and the difference between the elevations of the inner and outer poles determined by substraction. This difference is adjusted by adding or subtracting the desired air gap for the finished assembly and the resulting dimension represents the overall thickness of the flux washer which will provide the desired air gap.

Third a preformed flux washer member is sized to the desired thickness by deformation. For example, the outer rim 50 of flux washer 28 may be crushed until the thickness dimension between the outer face 40 and the inner face 42 of lower wall 46 is equal to the desired dimension. This deforming step may easily be accomplished by placing the deformable flux washer in a press which may be controllably actuated to crush the flux washer to the desired thickness dimension.

While crushing of the flux washer element is a preferred manner of carrying out the process according to the invention, it is within the scope of the invention to alternatively deform other portions or elements of the magnetic assembly represented by the stator 24, armature 26 and flux washer 28. For example, the outer or inner ends of the poles of either the armature or the stator could be crushed or

squeezed to alter their elevational dimensions and thereby obtain the desired air gap 44. In still another variation, the web 30 of the stator or the corresponding web of the armature could be bent a small amount in order to alter the relative elevations of the inner and outer poles of the stator or armature in order to obtain the desired air gap. Alternatively, the corresponding web of the armature could be bent. These variations are merely examples of the possible ways in which elements or portions of the magnetic assembly could be plastically deformed in order to selectively provide the desired air gap during assembly of each injector unit.

Referring to FIG. 3, the addition of the inner rim 54 to the flux washer 52 may be advantageous in helping to avoid bowing of the flux washer during sizing by crushing. The flat flux washer 56 of FIG. 4 is proposed for use when the dimensions of the flux washer are not altered but the sizing of the air gap is accomplished by plastic deformation of either the armature or the stator, either by crushing the poles or bending the web as previously mentioned.

While the invention has been described by reference to various specific embodiments, it should be understood that numerous changes may be made within the spirit and scope of the inventive concepts described. Accordingly, it is intended that the invention not be limited to the described embodiments, but that it have the full scope defined by the language of the following claims.

Claims

What is claimed is:

1. A method of adjusting an air gap for a solenoid device having at least three gap defining elements including a stator having inner and outer poles and partially surrounding a magnetic coil, an armature having inner and outer poles movable toward and away from the stator poles and a flux washer between the armature and one pair of opposing poles of the stator and armature, the armature being engageable with at least one of the stator and the flux washer and, when so engaged, being spaced from the other by said air gap, said method including the steps of:

determining the gap defining dimensions of all but one of the elements;

determining the dimensions of said one element required to form the desired air gap upon assembly with the others of said elements; and

sizing said one element to said required dimensions;

said method characterized in that sizing of said one element to the required dimensions is carried out by deformation of a preform.

2. A method as in claim 1 characterized in that said one element is the flux washer and said sizing step includes crushing of a washer preform to a required thickness dimension.

3. A method as in claim 2 characterized in that the required thickness of the flux washer and the gap defining dimensions of the other elements are determined by measuring inner and outer elevations of the stator and armature, calculating the difference between the totals of the measured inner and outer elevations, and adjusting the resulting difference by the value of the desired gap.

4. A method as in claim 1 characterized in that said one element is the armature and the sizing step includes crushing of one of

its poles to establish a required dimensional difference in elevation of the inner and outer poles of the armature.

5. A method as in claim 1 characterized in that said one element is the stator and the sizing step includes crushing one of its poles to establish a required dimensional difference in elevation of the inner and outer poles of the stator.

6. A method as in claim 1 characterized in that said one element is the stator and the sizing step includes bending a connecting portion between its inner and outer poles to establish a required dimensional difference in elevation of the inner and outer poles of the stator.

7. A method as in claim 1 characterized in that said one element is the armature and the sizing step includes bending a connecting portion between its inner and outer poles to establish a required dimensional difference in elevation of the inner and outer poles of the armature.

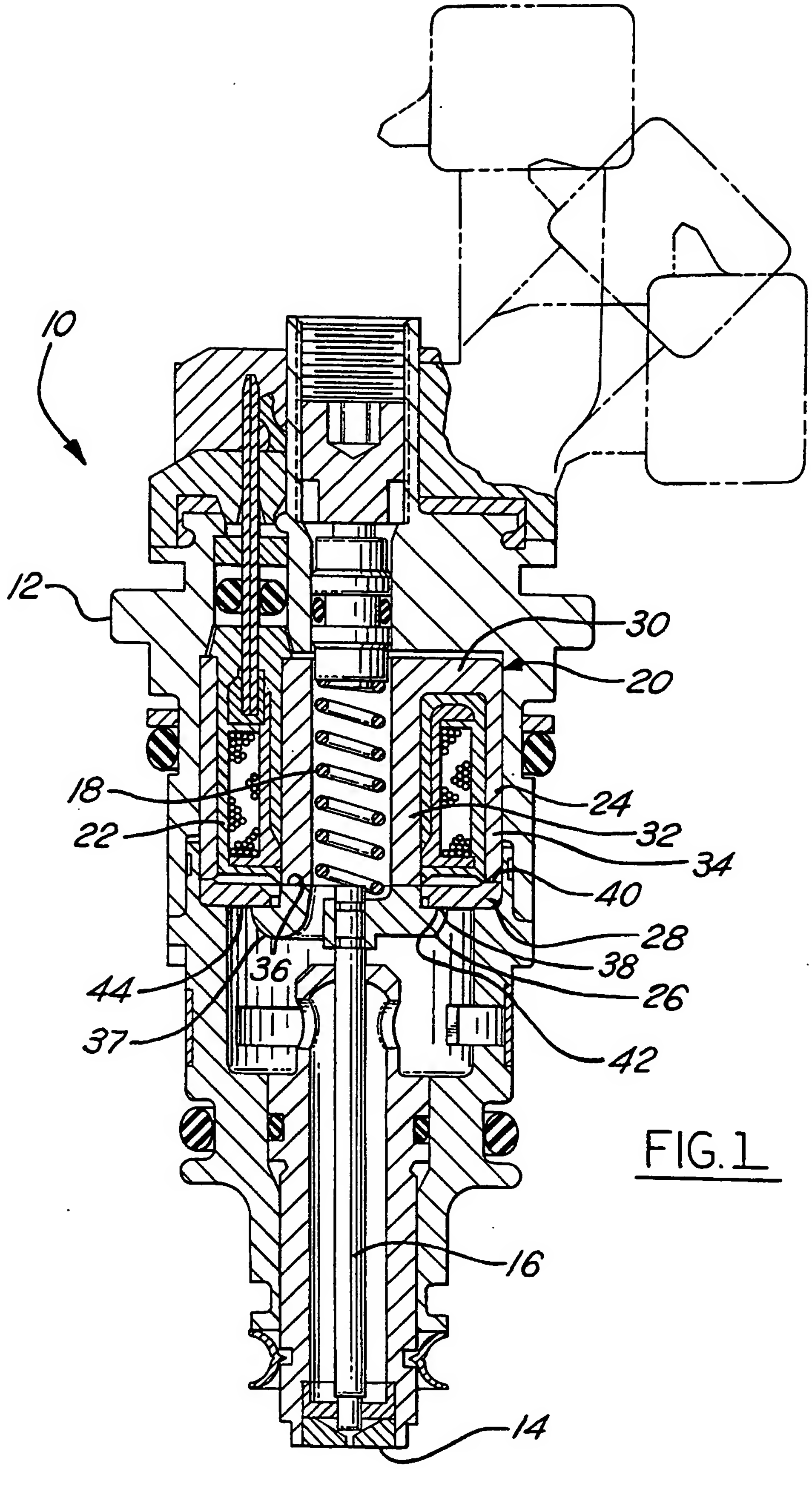

FIG. 1

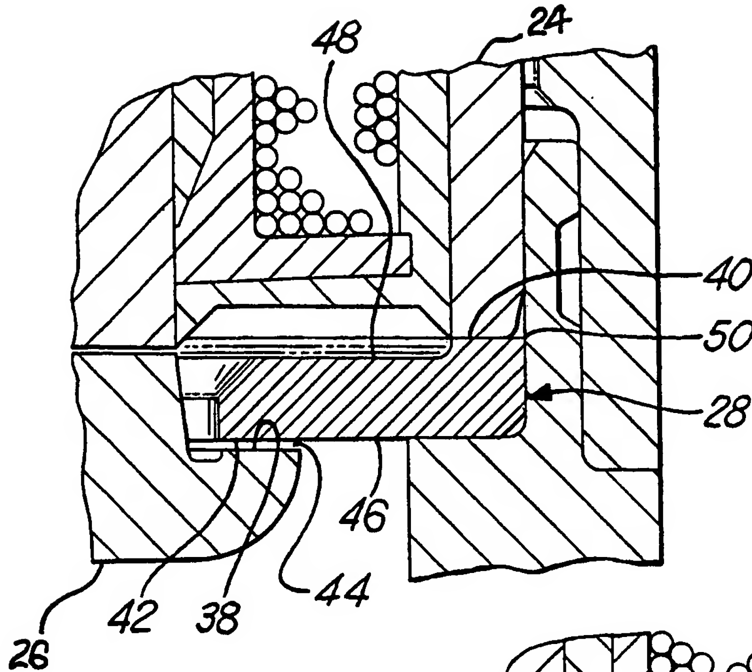

FIG.2

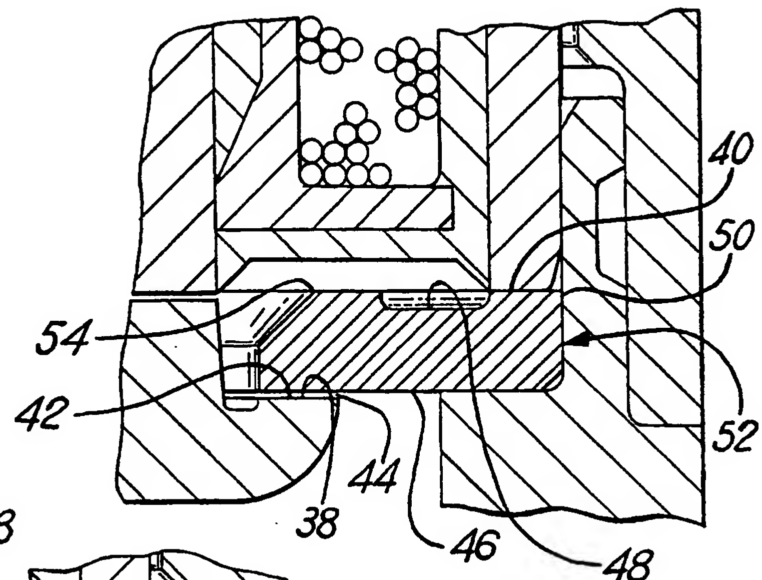

FIG.3

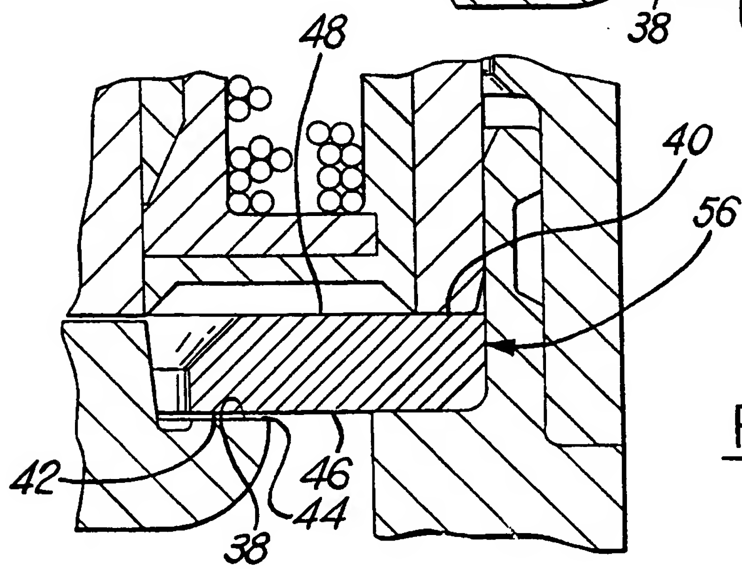

FIG.4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/08228

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F02M51/06 H01F7/08 H01F7/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F02M H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,4 475 690 (HASCHER-REICHL) 9 October 1984	1
A	see column 2, line 56 - column 4, line 41; figure	2

A	US,A,5 417 373 (FACCHIN) 23 May 1995 see the whole document	1

A	US,A,4 610 080 (HENSLEY) 9 September 1986 see the whole document	1

A	GB,A,2 058 466 (ROBERT BOSCH GMBH) 8 April 1981	

A	EP,A,0 215 527 (SPICA S.P.A.) 25 March 1987	

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
4 October 1996	14.10.96

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP,A,0 216 943 (IBM DEUTSCHLAND GMBH) 8 April 1987 -----	

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International Application No
PCT/US 96/08228

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-4475690	09-10-84	DE-A-	3139669	21-04-83
		EP-A-	0076459	13-04-83
		JP-C-	1680603	13-07-92
		JP-B-	3045267	10-07-91
		JP-A-	58072782	30-04-83
US-A-5417373	23-05-95	WO-A-	9522000	17-08-95
US-A-4610080	09-09-86	CA-A-	1264624	23-01-90
		EP-A-	0216010	01-04-87
		JP-A-	62032275	12-02-87
GB-A-2058466	08-04-81	DE-A-	2936425	02-04-81
		DE-C-	2954588	28-06-90
		FR-A-	2468757	08-05-81
		JP-C-	1682632	31-07-92
		JP-B-	3043465	02-07-91
		JP-A-	56044450	23-04-81
		JP-A-	4090350	24-03-92
		JP-B-	5012548	18-02-93
		US-A-	4365747	28-12-82
		US-A-	4481699	13-11-84
EP-A-215527	25-03-87	NONE		
EP-A-216943	08-04-87	CA-A-	1249625	31-01-89
		JP-B-	5033666	20-05-93
		JP-A-	62035857	16-02-87

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